Hill (J. W.)

AMERICAN SOCIETY OF CIVIL ENGINEERS.

The Quality of Water Supplies.

—BY—

JOHN W. HILL, M. Am. Soc. C. E.

presented by the author

WITH DISCUSSION

By DESMOND FITZGERALD, CHARLES FRANCIS, WILLIAM E. WORTHEN, CHARLES H. SNOW, S. WHINERY, WILLIAM P. MASON and JOHN W. HILL.

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THE QUALITY OF WATER SUPPLIES.

By JOHN W. HILL, M. Am. Soc. C. E.

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WITH DISCUSSION.

The presentation to the Society of a paper on the self-purification of streams, by Dr. Charles G. Currier,* and one on fresh water algæ, by George W. Rafter,† M. Am. Soc. C. E., is the writer's apology for offering a paper on a subject, which, from its title, might seem better addressed to a health congress than to a society of engineers. But health boards and medical societies are usually powerless to rectify the evils to which attention is called by this paper. They may raise objections to existing conditions, and propose remedies, but to the engineer is finally entrusted the work of design and construction. Moreover, if the engineer engaged on a work of public water supply makes no mistake in selecting the source, or, the source being open to suspicion, he adopts the proper remedies to avoid injury to the consumers of water, then no question can be raised by health boards and medical associations. After all, it seems that health officers, physi-

* Trans. Am. Soc. C. E., Vol. XXIV, page 21.

† Trans. Am. Soc. C. E., Vol. XXI, page 483.

cians and analysts of water supplies can only demonstrate the evils, and aid the engineer in determining the cause, while the processes or devices for meeting or avoiding the danger are purely engineering problems, and as such should always be worthy of attention at our hands.

To members of the Society engaged in designing or operating works of public water supply, any inquiry into the quality of drinking water is usually always welcome, and, while the writer does not expect to offer any new facts, he hopes to be able to present some of the old ones in a way to carry conviction to doubting minds, of one of the principal dangers which now invests our sources of drinking water.

It is believed that water is a carrier of certain diseases, namely, cholera, typhoid fever and diarrhœa, and that the specific germ is transmitted from the sick to the well through the medium of drinking water.

It is also held by some investigators that the breaking up of vegetable detritus in drinking water may be the cause of disease, and it is well known that mineral poisons may be imbibed in drinking water.

Cholera is said, by Dr. Shakespere and others, to originate *de novo* in India, from the contamination of their drinking water by the filth of the native inhabitants,* and epidemics of typhoid fever and diarrhœa have been traced to wells,† or other sources of water supply, or to the ice used in cooling water,‡ the germs of disease being locked up in the ice and released upon its melting in the water.

Now, while water is held to be a carrier of disease germs, the writer is not aware that any investigator has ever claimed to have seen these germs in water, even under the highest powers of the microscope; and the evidence that water is such a carrier of pathogenic bacteria is obtained by inoculation from water samples, of nutrient media in test tubes, or on culture plates.

Thus, by methods quite indirect and open to grave errors of judgment in the hands of any but an expert, the fact of water carrying the spores of disease germs is established.

To those who have given the subject of bacteria no special study, it is proper to remark that the modern methods of bacteriology have

* "U. S. Rep. on Cholera in Europe." Dr. Edward O. Shakespere, 1890.

† "Bacteriological Study of Drinking Water." Dr. Victor C. Vaughan, Ann Arbor, Mich., 1892.

‡ "Water Supply." W. R. Nichols, 1883.

clearly proven that the soil, air and water swarm with bacterial life, and that countless micro-organisms and presumably organisms which cultivation and the microscope have not yet revealed, are steadily at work feeding upon and destroying the organic matter in these elements, and that we who drink water and inspire air are taking into the system thousands of these bacteria or their spores every day of our lives, from which it follows that first, all these bacteria are not pathogenic in character; or, second, the condition of the circulation or tissues of the human system are such as to repel their action and deprive them of a fertile soil, both of which are known to be true.

Of the so-called pathogenic bacteria, only a few have been proven to be the cause of disease, and of those which are known to accompany disease, although they may not cause it, they are said to be only active when brought in contact with a vitiated circulation, or with surface or internal lesions.

There can be no blood poisoning, excepting the germ of "septicæmia" be introduced into the circulation, and it can be introduced into the circulation only through a lesion of the skin or membrane.

So long as water contains organic matter in process of destruction, so long will bacteria be present in water, and some of these may be pathogenic bacteria, and lay the foundation for dangerous disease.

In considering the number of colonies of bacteria per unit of volume in a given water sample, it has been assumed that the number bears a just relation to the amount of organic matter in such water, and that any treatment of the water which diminishes the number of colonies of bacteria really does this by reducing the quantity of organic matter upon which such bacteria subsists. If all the bacteria, by any process, are removed from a sample of water, it is held that such water has been wholly deprived of organic matter, and, conversely, bacteria or other organisms harmless or harmful (to human life) cannot survive in a water wholly deprived of organic matter in a state of dissolution. It is possible that an absolutely pure water might be the carrier of a disease germ which accidentally came into it, but it is not likely that such germs could long subsist in a water deprived of pabulum for them, and they would soon perish for lack of subsistence, for bacteria, like any other vegetable growth, must have the proper nourishment, to sustain life.

The simple knowledge that organic matter exists in water, without

a knowledge of its source, is not worth much. Sugar is organic matter; so is excreta. Sugar in water would not be considered dangerous; excreta in water would be highly dangerous. Any organic matter in water will show an excess of ammonias above the normal, whether this be derived from safe organic compounds or from decomposing wastes; hence, a knowledge of the organic matter, independent of the knowledge of the kind of source of such matter, does not furnish reliable information upon the quality of a water sample. The chemical test for chlorine is usually relied upon to determine the probable source of organic matter, chlorine, usually from animal urine, indicating a sewage origin.

In classifying waters from high elevations, where the probabilities of sewage contamination are small, and waters from lowland sources, where the probabilities of sewage contamination are large, Prof. Frankland considers that the source or cause of pollution is more important than pollution itself, and proposes that waters from elevated sources may contain from one and one-half to twice the amount of organic elements (organic carbon and organic nitrogen) of lowland waters and still rank with the latter of any class (Frankland's "Analysis of Waters," page 94).

PARTS PER 100 000 OF ORGANIC ELEMENTS IN WATER.

Class.	Upland source.	Lowland source.
1. Water of great purity....	0.2	0.1
2. Water of medium purity.......	0.2–0.4	0.1–0.2
3. Water of doubtful purity......	0.4–0.6	0.2–0.4
4. Impure water.................	0.6 +	0.4—

The bodies of fresh water at lowest elevation of any geographical system are the rivers and lakes, and these are essentially the channels of discharge for the sewage of organized communities, as well as for that larger volume of decomposable wastes in the surface drainage from urban and agricultural territory; hence, organic matter in lowland waters, whether of rivers or lakes, is generally from sewage or semi-sewage sources, while organic matter in the waters gathered at high elevations is generally the result of vegetable detritus in the run-off of rainfall on unimproved or virgin water-sheds.

Chemistry enables us to determine as compounds containing nitrogen the organic matter in solution, while the microscope assists us in

the examination of the organic matters in suspension, but in doing so it has this advantage over chemistry, in that the examination is direct and not so much dependent on the personal equation as the results of chemical analysis.

A sample of rich sewage under microscopical observation will show micro-organisms capable of identification, together with masses of loose flocculent matter, which some term amorphous matter, but which the writer has indicated in his notes of tests as broken-up albuminous and cellulose matter. Such a sample, under continuous examination, will show a reduction of this loose matter, and in due time it will altogether disappear, the micro-organisms absorbing it, to support life; and with the disappearance of organic matter, there is a reduction of the vegetable and animal life in the water sample.

It is sometimes asserted that certain organisms are only found in good water, but the writer has observed, for instance, *Copepoda* in good cistern water, as well as in water known to be defiled by household wastes. If *Copepoda* alone were found in a water sample, the writer should not regard it as bad; but if associated with other and lower animal organisms and the lower kinds of filamentous algæ, he would consider such water as unsafe for drinking purposes. What is true of this particular organism, which is commonly found in soft waters, is true of any other organism supposed to inhabit pure water.

In order to approach the question of water pollution properly, it must be borne in mind that while polluted water is held to be the cause of certain diseases, exactly how it acts on the human system is not well known. Bacteriologists generally regard the Koch cholera bacillus, and the Eberth typhoid bacillus, as the causes of these diseases, but this view is not shared by all physicians as it should be if the proof of cause was sufficient, although common prudence should decide us in rejecting any water known to contain the cholera or typhoid bacilli, whether these germs be regarded as the cause or result of disease, since they indicate the presence of the cause if not the cause themselves.

The presence of putrefactive bacteria in a water sample is an evidence of decomposition going on in the water, but the disease, if any be derived from the use of such water, may not be due to the bacteria at all, but to some ptomaine obtained from the decomposition of the or-

ganic matter, or, as Professor Vaughan terms it, to some "toxicogenic" property of the water.*

While water may be a carrier of the cause of cholera, diarrhœa and typhoid fever, it is only the latter in which we are specially interested. Cholera may never arise *de novo* in this country, and diarrhœa traceable to a polluted water supply is seldom fatal, while typhoid fever is with us always, and, apparently, in all localities, and its ravages of the young, the bright, and the promising, are more to be dreaded than any of our infectious diseases, if we may except diphtheria, and, in the writer's opinion, it is more dreadful than diphtheria, because the latter is usually confined to the very young and undeveloped, while typhoid strikes down its victims as it were when they are on the very threshold of life; and, in discussing the danger of a polluted water supply, it will be from the single standpoint of its influence in the propagation of typhoid fever; although it may be well to remark, that, apart from the specific germs or sources of the diseases mentioned, water may contain common putrefactive bacteria which may not be hurtful in themselves, but which indicate the probability of the presence of organic matter in some of which there may be danger.†

The pumping of water for domestic uses from a source known to be polluted by sewage or otherwise cannot be too strongly condemned. The delivery of water containing the elements of fatal disease to a confiding and helpless community, partakes, in the writer's opinion, of the worst kind of criminality, and no one engaged in such work who is aware of this, or who refuses to apply the tests which will reveal the danger, if it exists, can hope to escape censure, even if, for lack of laws, he may escape a just punishment for his crime.

An attempt to kill people by the systematic distribution of a deadly poison would be met by the prompt arrest and punishment of the offender, but the delivery of a water for domestic uses as fatal to some as a dose of strychnine is permitted without a word of complaint. Why is this? Must we shut our eyes to the fact that polluted water is dangerous to health? Must we reject the results of the work of the patient investigators who have demonstrated over and over again that danger, often death, lurks in our drinking water? Or shall we recognize the peril and address ourselves to the task of rectifying an evil

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* "A Bacteriological Study of Drinking Water," by Dr. V. C. Vaughan, 1892.

Parkes' "Manual of Practical Hygiene," 1883.

greater than any other connected with the art of engineering? For the saving of human life, whether accomplished by medical remedies or the sanitary arts, is the noblest work to which man can set his hand.

The difficulty of procuring a satisfactory supply of potable water for large or even small communities, is well understood by the engineers engaged in this line of work. Sources of supply, which 10 or 15 years ago were thought to be safe in a sanitary aspect, are now open to grave suspicions of quality; and it is not extravagant to assert that few of the larger cities of the country enjoy a public source of water supply which satisfies the ordinary requirements of a potable water.

The increased sewage pollution of rivers and lakes which might furnish a safe drinking water is partly responsible for the difficulties surrounding this problem. But, apart from the special sewage pollution by organized communities, there is a pollution of streams and lakes by the ordinary surface drainage from agricultural water-sheds which often renders the waters of such unfit for drinking purposes.

Several years ago in discussing this question, the writer took the ground that, as the proportion of water used for drinking purposes was ½ per cent., or less, of the whole quantity consumed by the takers from a public source, the better plan was not to attempt to secure the whole supply of potable quality, but to render any water available fit for drinking purposes by domestic filtration. Later experience satisfies him that this plan will not answer for several reasons:

1. All consumers of a public water supply cannot, or will not, use domestic filters.

2. There is no domestic filter which is absolutely proof against the dangers of polluted water.*

3. Even if a satisfactory filter was obtainable, it is doubtful if the average householder would give this the attention it would require to keep it at all times in condition to act as a safeguard.

In view of which the writer has reached the conclusion that, if the consumer is to have a safe drinking water, it must come to him in this condition through the public water mains. In other words, the matter of purity must be looked after by the municipal corporation, or the water company. The prevalence of typhoid fever in many cities and

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* Parkes, "Practical Hygiene," 1892.

towns having a public water supply is evidence of the water now generally furnished to consumers as being unpotable, and that the municipal corporations, or the water companies, are furnishing to their consumers the spores, or organized bacilli of the Eberth germ, or material from which the specific virus of typhoid is generated.

In speaking of the typhoid bacillus in water, it should be remarked that this has never been seen with the microscope without previous cultivation of the germ in nutrient media. Nor has it ever been demonstrated, so far as the writer is aware, that the presence of bacilli in water can be proven, excepting by delicate and difficult bacteriological processes.* It is well understood that the infective element of typhoid fever can be present in water and the chemical test be powerless to disclose it.†

In his excellent treatise on Sewage Disposal, Mr. Rafter aptly remarks "that absolute immunity from danger (by sewage pollution of water supplies) cannot be hoped for. There will always be some risk, even after the best has been done that is possible in any given case. And, so far as public water supplies are concerned, the true remedy lies in the direction of an absolutely uncontaminated source."‡

The only objection that can be raised to Mr. Rafter's method of securing an undefiled water supply is the great difficulty of its general application. For small communities requiring but a few hundred thousand gallons of water per diem, a supply of potable water can often be had from deep driven wells; but for large cities using many millions of gallons daily, such a source of supply is out of the question. It is doubtful if the water gathered on inhabited and improved water-sheds and impounded in large reservoirs for city supply, can be regarded as absolutely safe water for drinking purposes. Neither is it proper that lakes without current or circulation, and often the receivers of city sewage, should be considered as undefiled sources of supply.

Rivers receiving the sewage of cities and towns on their banks, and on the banks of their tributaries, certainly are not within the limitation of Mr. Rafter's sources, and where, then, are we to obtain the large volumes of water daily required by our larger cities, and have the same free from contamination at its source? Cities located in the moun-

* Sternberg, "Manual of Bacteriology," 1893.

† Frankland, "Water Analysis," 1890.

‡ Sewage Disposal, by Geo. W. Rafter and M. N. Baker, 1894.

tainous regions can impound water at elevations so high as to avoid pollution from all sources but the atmosphere, and this, as well as water, is always purer than in the valleys and on the lowlands. But for the larger cities of the middle States, having no mountain sources within practical reach, and without visible sources of supply which will satisfy Mr. Rafter's requirements, our only resource is to accept such water as is available in large quantities, and so deal with it as to render it innocuous to health.

It is too frequently asserted or implied in text books and reports on sewerage, that the noxious properties of sewage are destroyed or safely mitigated by proper dilution, but if sewage should be the carrier, as it undoubtedly often is, of pathogenic germs, how can dilution remove them? It may reduce the number per unit of volume of the mixed sewage and water, but the germs are still there, and when taken into the system through drinking water, may produce just as serious results to just as many people as if no dilution had occurred. Dilution may reduce the chances of any single individual imbibing a fatal germ, but the germ itself will be just as dangerous when it is imbibed. In speaking of germs in this connection, it must be understood that they are not limited to organized bacteria, but are meant to include any toxic property of water which may be derived from a sewage source.

The common opinion that the number of germs in a water sample is an index of its potability is apparently not well founded; for instance, from Dr. Victor C. Vaughan's extensive and able investigation of Michigan's waters, we note, that water from Torch Lake, Mich., containing 5 284 germs per cubic centimeter in a beef tea solution was fatal to rats, and well water from the same place, containing only 20 germs per cubic centimeter in a culture of beef tea, was also fatal to rats. Both of these waters were suspected of being the cause of typhoid fever. River water from Mount Pleasant, Mich., containing 3 000 germs per cubic centimeter in a culture of beef tea, had no effect on rats, while artesian water from Gladwyn, Mich., containing 10 germs per cubic centimeter in the same culture, was fatal to guinea pigs. Lake water from Soudan, Minn., containing 459 germs per cubic centimeter in the same culture, had no effect on rats, while well water, also from Soudan, containing four germs per cubic centimeter in the same culture, was fatal to rats.* Of course, Dr.

* "A Bacteriological Study of Drinking Water," by Dr. V. C. Vaughan.

Vaughan's tables contain illustrations the opposite of these, but these demonstrate clearly that the number of germs is not a safe index of the quality of the water sample (see Sternberg's "Manual of Bacteriology," page 558).

What is desired is not so much that the germs be reduced to a small number, as it is to eliminate altogether those of a pathogenic character. A man in jumping a brook must accomplish the feat in one leap. He cannot jump half way across and rest, and then jump the other half at his convenience. So it seems to me in dealing with the subject of water purification; we cannot partially purify it, and then deliver it to the consumers, without great risk. The bacteria, or other cause of disease, must be wholly eliminated, or we will be in the predicament of the man who attempts to cross the brook in two jumps, we will be worse off than if we had remained on the hither side; for a partial purification of our drinking water will beget a feeling of security which is false and may lead to serious results, while no attempt at purification at all will leave us on our guard against a polluted water, and cause us to avoid the drinking of it altogether.

In reports of filters tested for the reduction of bacteria it is customary to state the condition of the water in bacteria per cubic centimeter before and after filtration. These are given as the average per cubic centimeter and often the number after filtration may be as low as three or four, and the writer has seen it stated as low as one per cubic centimeter. An ordinary drinking tumbler contains half a pint, or about 230 cu. cm., and with the best of filtrated water so low in bacteria as one or two per cubic centimeter, a person may imbibe from 250 to 500 bacteria in drinking a single glass of water, some of which may be pathogenic and produce typhoid fever, or some other less dangerous disease.

Heretofore the writer has concurred in the popular belief that ordinary filtration of polluted water through some of the well-known modern filters would render it reasonably safe for drinking purposes, but from recent investigations of his own he is compelled to abandon this view. In the case of Cincinnati, with which he is familiar, the public water of which is notoriously unfit for drinking, nearly every public house and many business establishments are supplied with some form of sand filter or with the Pasteur filter, and yet Cincinnati takes high rank for its number of cases and deaths from typhoid fever.

Dr. Frederick Kebler, a skillful bacteriologist and eminent physician, informs the writer that even the celebrated Pasteur filter is not proof against the passage of bacteria; that these attach themselves to the outside of the porous porcelain tube, and, by growth and fission, eventually appear upon the inside of the tube, and may be found in the filtered water; and, from the writer's own examination of a section of a Pasteur filter tube under the microscope, he conceives that the pores are large enough to pass bodies of considerable magnitude, *i. e.*, from a microscopic standpoint.

Filtration through a Pasteur tube can accomplish no nitrification by bacterial agency, and poisons, or the base of ptomaines in solution, are certain to be found in the filtered water.

It is said by the manufacturers that the porosity of a Pasteur filter is equivalent to 1 micron (u), or $\frac{1}{25000}$ in. Now, the average diameter or thickness of a typhoid bacillus is $\frac{1}{5}$ micron (u),* and the spores very much less.† From which it appears that the Pasteur filter tube is open to the unrestricted passage of the germs and their spores, if such should have a habitat in the water.

There being no nitrification in passing through a Pasteur tube, no change can possibly be effected in the organic matter in solution in the water. For this, as we understand, can only be accomplished by boiling, chemical reactions, or by the nitrifying action of bacteria. In this respect a sand filter, properly constructed and worked, should yield a better filtrate than a Pasteur filter. But, as sand filters are usually worked, it is probable that they not only fail to remove organic matter in solution, but some of that in suspension may pass through, the only test of the filtrate being its limpidity, and it is well known that waters may be clear as crystal and still contain much organic matter in suspension, and all it ever had in solution. Clear water may be very dangerous water, as witness some of the spring waters sold in Boston and vicinity recently tested by Prof. T. M. Drown.‡

The so-called sanitary tests of water by chemists, when unsupported by careful microscopic tests, and this again fortified or checked by tube and plate cultures from the water sample in question, cannot be accepted as proof of quality, since "the existence of an

* Cruikshank, "Manual of Bacteriology," 1890.

Rafter & Baker, "Sewage Disposal," 1894.

‡ Twenty-third Annual Report, Mass. State Board of Health.

infectious property in water cannot be proved by chemical analysis alone." *

The Pasteur filter acts simply as a very fine strainer, and is capable only of removing impurities in suspension in the water, impurities in solution being wholly unaffected by it. If the water upon which the filter acts is already chemically pure, and it is desired to remove organic matter in suspension, such as animal and vegetable organisms, clay silt, etc., then the filter can be relied upon to restrain these in passing through the tube. The popular idea, shared by many physicians, that the Pasteur filter is a safeguard against all manner of impurities in water is a fallacy. A sewage-polluted water may be as dangerous to health after it has been run through a Pasteur filter as it was before.

To satisfy himself upon this question, the writer has run through Pasteur filter tubes solutions of aniline purple, sulphate of quinine, sugar, starch, sulphate of copper and carmine, and has recovered in the filtrate all, or nearly all, of the original weight of the solid in solution. In making this test generally 1 gr. of the solid was dissolved in 200 cu. cm. of distilled water.

Of late years many Pasteur and sand filters have been installed in Cincinnati, and the general belief is established among the people that water from them is deprived of pathogenic properties, and yet the case and death rate from typhoid fever seems to be unaffected by their use. The writer thinks this is due to the fact that the spores or the bacilli of the typhoid germ (if such exist in water in a developed state), as well as any poisons in a solution, pass unchanged through the pores of the tube. The porosity of the Pasteur tube is probably much less than that of any sand filter in use in the city, and any matters not intercepted by a Pasteur tube would pass with less restriction through the bed of sand. The writer does not understand that any claim of nitrification is made for the common continuous sand filter, but that this, like the Pasteur, is expected to act simply as a very fine strainer.

Of course, it is unreasonable to suppose that all typhoid cases in Cincinnati can be traced to the use of water from Pasteur and other filters, but in some cases it can be so traced. A single case wherein filtered water alone was used as a beverage raises a just suspicion of the capacity of the filter to effectually restrain the typhoid bacillus or

* Frankland Water Analysis, 1880.

its spores from passing through the porcelain tube or bed of sand, or raises a doubt of the Eberth bacillus, or any other water bacteria, being the true cause of typhoid; and this suggests that the germ theory of disease, so ably expounded by Pasteur and Koch, is not universally accepted, many still holding to the Leibig theory, namely, "that disease is due to organic matter in process of decay communicating the elements of decomposition."

It is known that a Pasteur filter after it has been in use for some time may permit the passage of bacteria, and it will be necessary at frequent intervals to subject the tubes to a high temperature for the purpose of destroying all organic matter contained in the porous porcelain.*

Dr. Currier has shown that plate cultivations of bacteria can be made from water after it has passed through a Pasteur filter,† indicating that such water is not sterilized. It has been stated that the channels through the Pasteur tube are said by the makers in this country to be about $\frac{1}{25000}$ in., or 1 micron, in diameter, if considered as a round perforation. Now, many bacteria are less in diameter than a micron (Cruikshank), and the spores of all bacteria are much less in diameter than the developed organism. May it not be possible that the smaller bacteria or their spores pass unchanged through the porous Pasteur tube? The writer is aware that this theory is contrary to the common belief that water absolutely sterile and fit for bacteriological purposes is obtained by this mode of filtration, but the question is submitted for what it is worth. He feels safe, however, in asserting, from his own observation here in Cincinnati, that if absolutely sterile water is obtained from Pasteur filters, that the cause of typhoid fever cannot be found in the Eberth bacillus, but is due to a specific poison or ptomaine in the water, which the filter is powerless to remove.

From experiments by Drs. Frankland and Tidy‡ on the sewage of London and other English cities, the organic matter in solution will range from an equal amount to twice the quantity in suspension. Experiments by Mr. Dibden on London sewage show the ratio of dissolved to suspended matter to be as 1.00 to 0.77, or, of the organic matter in sewage, the larger part is in solution and wholly beyond the influence of any filter which acts simply as a strainer.

* Sternberg, "Manual of Bacteriology," 1893.

Trans. Am. Soc. C. E., Vol. xxiv.

‡ Tidy, "Treatment of Sewage," 1887.

The only effective filtration is that in which the organic matter in solution, as well as the suspended matter, is removed from the water, and any filter failing to do this cannot be considered a success from a hygienic standpoint.

To determine the character of any water before and after filtration, or of any water about to be adopted for public uses, tests should be made chemically, for the ammonias, chlorines, nitrites and nitrates, for solids and hardness of water, and, if suspected, for mineral poisons, microscopically for the organisms and amorphous matter; and bacteriologically for the bacterial life in the sample of water. If the chemical test fails to develop any dangerous matter in solution, if the test with the microscope shows no low or objectionable organisms and no amorphous matter, and the test for bacteria reveals no pathogenic or parasitic microbes, such water, in the light of present knowledge, is possibly the best for drinking purposes we can hope for.

The city of Cincinnati has been well supplied for several years with mechanical filters, and yet, from statistics gathered by Dr. Stallard, of San Francisco, this city, of six in this country and five in England, stands at the head in mortality from typhoid fever, having a death rate four and a half times as great as that of London, higher than that of Philadelphia, and twice as great as Boston.

Admitting typhoid to be a water-borne disease, then it appears from its prevalence in this city (Cincinnati) that the filters in use here are worthless in combating the cause. In other words, the danger from typhoid seems to be as great after our water has been filtered as before.

The Ohio River, before it reaches Cincinnati, receives the sewage and surface drainage of upwards of 100 cities and towns, many of which have systems of sewers to facilitate the discharge of their sewage into the river or its tributaries. When the stream reaches Cincinnati the dilute sewage is pumped into the reservoirs and served to the people. What is true of the river at Cincinnati is emphasized as we proceed down stream, this city enriching the sewage-laden stream to the extent of 36 000 000 galls. per day, as a dry weather discharge, and, of course, many times that quantity during periods of rainfall, when our street wastes are washed into the sewer and carried into the river.

The water supplied to Cincinnati is not worse than that supplied to some other cities. But negligence or indifference in this respect by

our city does not justify it in any other, and if the same energy that is given to politics by the officials of Cincinnati was applied to the securing of a supply of pure water, there is no doubt that our water quality would be improved, and our alarming death rate from typhoid fever be diminished. Here, at least, and possibly in other cities, politics and water do not mix, and the harvest of our dearest idols goes on without restraint.

While it is not certainly established that typhoid cannot be acquired by other processes than water, milk or food, the weight of evidence now before us is that it is nearly always brought into the system through drinking water.

Considering typhoid as a water-carried disease, and assuming that one who drinks only pure water cannot contract it, then it follows that with pure water universally supplied to consumers, typhoid will no longer exist.

The Massachusetts State Board of Health has made extensive experiments on the filtration of water through beds of sand and loam, with very satisfactory results,* but at such slow rates of filtration (23 to 69 galls. per square foot of sand bed per day) as to discourage the adoption of this method in treating large volumes of water.

A report before the writer of a test of one of the mechanical sand filters shows about the same results in the removal of bacteria at rates of filtration as high as 166 000 000 galls. per acre per day, as the Lawrence experimental filters give at rates of 2 000 000 galls. per acre per day; or, while working at a rate of filtration over 80 times as great, the mechanical filter gives the same efficiency in removal of bacteria.

It is common for physicians in cases of doubt of the purity of a water supply to recommend that water for drinking purposes be boiled, but the boiling of water renders it insipid and unpalatable, and it is claimed by some of the manufacturers of filters that water deprived of certain of its natural gases and solids in solution (as it will be by boiling) is not as wholesome as natural waters. The writer has been unable to obtain any reliable information of the influence on the human system of the harmless salts and gases in solution in natural waters, and is in doubt whether the continuous use of boiled water as a beverage will be deleterious. Considering that filtered and boiled water will be limpid and sterile, and deprived of all toxic properties,

* Twenty-third Annual Report, Mass. State Board of Health.

and assuming that such water will not be injurious to the system, may not the problem of a safe drinking water finally be solved by combined filtration and distillation? If carried out to its legitimate conclusion, this would mean the treatment of a sufficient quantity of water by the corporation for drinking and culinary purposes, and the delivery of this to consumers through an independent system of comparatively small mains. But the expensive apparatus for distillation, the cost of duplicating the street mains, even with pipes of small diameter, and especially the large annual expense of operation, might at first sight seem to prohibit any attempt by this process to purify water on a large scale.

As this question is sometimes raised in the discussion of quality of water, it may be of advantage to inquire what will be the cost of procuring absolutely pure water by filtration and distillation combined.

Assuming a daily consumption of 1 000 000 galls. of potable water, or 347 100 lbs. per hour, an efficiency of 75% for the evaporating apparatus = 11 250 thermal units per pound of coal, and an average of 1 124 thermal units required per pound of water evaporated, then 1 lb. of coal will distill 10 lbs. of water at atmospheric pressure, and the consumption of coal will be 417 tons (2 000 lbs.) at $2 per ton, or $834 per day.

Estimating 3 lbs. of water evaporated per hour per square foot of heating surface, then to deal with 1 000 000 galls. per day there will be required 115 700 sq. ft. of heating surface, and, allowing 2 000 sq. ft. per boiler, will require 58 boilers. Tubular boilers, 7 ft. diameter, 18 ft. long, will cost, set and trimmed, $1 800 each, or $104 400 for the requisite number. Boiler house to accommodate them, $35 000. Allowing 10 lbs. of steam condensed per square foot of cooling surface in condensers, then 35 surface condensers, with 1 000 sq. ft. of cooling surface to each, at a cost of $52 500, will be required. Two sets of sand filters, each of 1 000 000 galls. daily capacity, will cost $12 000; filter house, $4 000; pipes, valves and sundries, about $20 000; total, $227,900, or in round numbers, $228 000.

ANNUAL EXPENSE.

Interest on cost at 5%	$11 400 00
Sinking Fund to redeem bonds in 40 years, at 4%.	2 398 56
Fuel, $834 × 365 days	304 410 00
Labor, 45 men at $2 per day, 3 men at $5 per day, ...	38 325 00
Total, not including repairs.....	$356 533 56

and the cost of so purifying water will be about $\frac{1}{10}$ of one cent per gallon.

In the items of cost no allowance is made for pumping, because this would be required in any case, whether the water is treated before delivery, or pumped without treatment from the source to the consumer; nor for cooling water for the surface condensers, because the 97 or 98% of untreated water may be made to pass through the condensers as cooling water without extra cost.

This, however, is not the whole cost, for allowance must be made for a duplicate set of mains of small diameter to distribute this water. Estimating 250 miles of mains at an average cost of $4 500 per mile = $1 125 000.

ANNUAL CHARGE.

Interest on cost at 5%	$56 250
Sinking Fund to redeem bonds in 40 years, at 4%	11 835
Total	$68 085

Cost per gallon of water treated, about $\frac{1}{50}$ of one cent, or a total cost of $\frac{12}{100}$ of one cent.

Thus, water absolutely free from all germs and their spores, and free from all toxic properties and matter in suspension, can be obtained, if the work of purification is conducted on a large scale, at the rate of 8 galls. for one cent.

Is absolute immunity from typhoid fever, cholera and all other water-borne diseases worth this expense? The writer thinks it is.

Applying this total annual cost to the city of Cincinnati, with a population of 325 000, then the annual cost for the prevention of typhoid fever in this city, will be about $1 31 per capita. Considering the fact that we had over 400 cases of typhoid in the city from December 12th, 1893, to January 12th, 1894,* it would seem that this annual amount per capita is not great for immunity from this disease. Whatever may be said in this paper with reference to Cincinnati will apply to any other city similarly cursed with a public water supply which may, sooner or later, carry disease and death into every household.

From a communication to the writer by one of the principal manu-

* This statement was made to the writer by one of our leading physicians.

facturers of sand filters in this country upon the method pursued in freeing water of bacteria and dissolved organic matters in the continuous sand filter, he takes the liberty of making the following extract:

"Our method of purifying water is both chemical and mechanical, and consists in first treating the water with a suitable reagent, so as to render the objectionable matters insoluble and coalescent. We then allow five minutes to one-half hour for the coagulation or conglomeration of the precipitated substances, and finally pass the water through a filter bed of white machine-crushed quartz, which much resembles in appearance and size granulated sugar. The filtering beds in our filters average about 2 ft. in depth, through which the treated water is made to pass or percolate. The grains of the filtering material are sharp and easily retain the coagulated substances, whatever they may be, upon and in the interstices of the bed, so that the water after passing through the filtering bed of quartz emerges clear and brilliant and free from whatever objectionable impurities were previously aimed to be removed.

"The proper treatment of the water prior to filtration is as important as filtration itself, for it is evident that a filtering bed composed as above described would be too free and open to arrest only the grossest matters in suspension. A bacterium or spore is, as you know, from $\frac{1}{20000}$ to $\frac{1}{100000}$ in. diameter; while probably the smallest of the interstices in the bed would not be less than $\frac{1}{100}$ in. in breadth. There are, therefore, but two mechanical methods available for retaining these germs. One, which is the method followed by the Pasteur, being to provide crevices or passages through the filtering material a trifle smaller or finer than the smallest bacterium. The other method is to coagulate the bacteria into masses large enough to be retained by larger passages. To effect this coagulation or conglomeration of the bacteria, sulphate of alumina or alum is used. The action of the sulphate of alumina is briefly as follows: When it is added to the water it decomposes the bicarbonates of lime and magnesia always present in waters to a more or less extent, and the products of the double decomposition are sulphate of lime or sulphate of magnesia, and carbonic acid gas and hydrate of alumina. The former two are as soluble as they were originally, and remain in the water; the latter is, however, insoluble, and is precipitated as a white, gelatinous mass, and, being coalescent in itself, envelopes the bacteria which adhere to it, and, therefore, when this precipitate of alumina is filtered out of the water, the bacteria, spores and all the infinitesimal matter in suspension is retained in the precipitate, and the water, therefore, can be easily and rapidly filtered through a filtering bed that would be absolutely worthless if no chemical treatment were used.

"Regarding the dissolved matters would say that these are removed by precipitating them directly, as, for instance, where lime and

magnesia are objectionable, we use sal soda or soda ash or caustic soda to precipitate the lime as carbonate, and this precipitate can be readily filtered out with our filter, therefore depriving the water of its lime and magnesia which was originally in solution, as it is in some of our sparkling artesian waters; as a result, the water is rendered perfectly or practically soft. The dissolved organic matters are almost entirely removed in the same manner by the alumina at the same time the bacteria are removed. We further remove the dissolved organic matters by subjecting the waters to aeration, which consists in forcing air into the water, oxidizing the decomposable organic matter which converts them into nitrites or nitrates, which are inert and harmless. These are the three methods most generally used in the purification of waters, although there are cases where special treatment is required. The average amount of alumina used does not exceed one-fourth of a grain per gallon, which is but 32.55 lbs. per 1 000 000 galls., and costs about $1\frac{5}{8}$ cents per pound."

Apart from a bed of sand common to all such filters and which acts only as a strainer or intercepter of suspended matter, the purification of water by the continuous sand filter appears to depend upon—

First.—The use of alum as a coagulent, to act upon the bacteria and dissolved salts in solution.

Second.—The use of soda ash or other reagent for softening purposes.

Third.—Aeration to oxidize dissolved organic matter and convert these into nitrites and nitrates.

Regarding the use of alum in sand filters much diversity of opinion exists. The manufacturers of these filters recommend it because it produces a clear filtrate while working the filter at a high rate of delivery, but in such uses of the mechanical sand filter as have come under his control, the writer has discouraged the corporations or water companies in the use of alum or any other astringent for precipitating the suspended organic matters, fearing that the excessive use of the coagulent would result in injury to the animal system. He is informed, however, by several of the manufacturers of mechanical sand filters that no harm can result from a surplus of alum, because any excess above that required to precipitate matters in suspension will unite with the mineral bases in solution in the water and produce insoluble or harmless compounds, as sulphate of lime, sulphate of sodium and hydrated alum. Upon the other hand, the excessive use of alum in a sand filter in one of our Cincinnati hotels, several years ago, was believed at the time to have produced among the regular boarders serious

bowel troubles, which were said by physicians in attendance to be due to the action of the astringent in the drinking water on the absorbent vessels of the stomach and intestinal canal. At best, the alum probably acts only on matters in suspension in the water, and has no influence on matters in solution * if these are derived from sewage sources.

The use of sal soda, soda ash or any reagent for softening the water would be demanded from a strictly sanitary standpoint only with those waters of great hardness, since small quantities of lime and magnesia are not generally regarded as injurious to the human system.

If the results of Prof. Drown's experiments on the aeration of natural waters are to be accepted as conclusive upon this point,† then the claim for oxidation of dissolved organic matter and its conversion into nitrites and nitrates is a mistake. No such result will follow the aeration of water containing dissolved organic matter, but, as Prof. Drown shows, aeration may be beneficial in expelling from water objectionable gases in solution; as, for instance, sulphureted hydrogen, but no chemical reaction can be expected from simple aeration.

It will be noticed that the first step in the purification of water described by the writer's correspondent is the treatment with alum, and that the water is at rest for a period of from 5 to 30 minutes, to give time to the alum to act as a coagulent and precipitant. This would seem to indicate an attempt at intermittent filtration with the continuous filter, or would involve the alum treatment of water in settling tanks, somewhat after the style of the precipitating tanks used for the purification of effluent sewage.

A successful filter must remove both suspended and dissolved matter and the toxic properties in water, otherwise it will be of doubtful utility as a sanitary appliance, because the average citizen accepts such devices altogether upon the representation of the manufacturer, under the impression that he has a safeguard against disease from a water source, when in reality he has nothing of the kind, and his danger from water-borne disease may probably be as great after he filters his drinking water as it was before.

According to Prof. Baumeister,‡ we can safely drink a sewage-polluted water when the sewage and water are mixed in certain proportions, depending upon the amount of organic matter in the sewage and

* Parkes' "Practical Hygiene," 1892.

† Twenty-third Annual Report, Mass. State Board of Health.

‡ R. Baumeister, Cleaning and Sewering of Cities, 1891.

of that previously in the water. But he depends altogether on chemistry for the test of potability of the water, when it is well known that chemistry is powerless to reveal infectious properties or bacteria in the water. He states, upon German authority, that water may carry $2\frac{1}{3}$ grains of organic matter to the gallon and still be potable. Looking at the question from a chemical standpoint, this may be true, but from a broad, sanitary standpoint any organic matter in drinking water known to be from a sewage source is unsafe.

The statement by Prof. Baumeister that sewage containing 29.2 grains of organic matter to the gallon may be mixed with river water containing 1.2 grains of organic matter to the gallon in the ratio of 23 galls. of water to 1 gall. of sewage, and the mixture be safe for drinking purposes, seems to me to be very dangerous, because the sewage may contain the germs of typhoid fever, which no amount of dilution can eliminate. Moreover, advice like this, instead of promoting the purity of water supplies and the public health, is calculated to impair both.

It is but fair to state that Prof. Baumeister is looking at the matter solely from the standpoint of sewage disposal into running streams, and it is doubtful if the selfish motive of ridding a community of sewage by generally the easiest and cheapest method should be allowed to prevail when certain disaster to those who may draw their drinking water from the stream below is bound to follow.

In another paragraph Prof. Baumeister says:

"The objection may be raised to these computations" (relating to sewage dilution) "that the limiting amounts of organic matter in potable water was not fixed under a supposition that a part of it was human excrement."

But all sewers receive some human dejecta, and this at times may contain disease germs, and these germs mixing with a so-called potable water are dangerous. Adapting to our purpose the memorable words of Mr. Lincoln, any water likely to be adopted for drinking purposes may be safe to all people at some times; it may be safe to some people at all times, but it may not be safe to all people at all times, and the protection of those who may at some time be susceptible to its deleterious influences should warn us against the use of any drinking water known to contain organic matter from a sewage source.

Without regard to the manner in which we obtain our drinking water, whether, as Mr. Rafter suggests, "from an absolutely uncon-

taminated source," by filtration, or by filtration and distillation combined, it should never be cooled by melting in it natural ice from an unknown source. No objection can be raised to the melting of artificial ice from distilled water in our drinking water; and, when this is not obtainable, natural ice can be safely used only by placing it in a receptacle separate from that containing the water.

Water is an essential to human existence, 90% of the liquid portion of the blood is water, and of the corpuscles or disks in the circulation nearly 70% is water. Of all the many articles of diet upon which we subsist, none is so important to the support of life as water. With all other articles of subsistence we are usually very careful, not only to demand the best, but to insist that they be absolutely safe to take into the human system; with water, however, we drink whatever comes most conveniently to hand, with no inquiry, and seldom a thought, as to its fitness for the purposes to which it is applied in the animal economy; and yet one of the most dangerous diseases, typhoid fever, can be established in the human system through the medium of drinking water. For, even in the few instances of its being traced to the distribution of a polluted milk, it has been shown that the remote cause or origin was in a typhoid-tainted drinking water.

In many States a human life has a fixed legal money value. The law of Ohio places the worth of a man's life at $10 000. If every fatal case of typhoid fever in the United States is multiplied by this amount the product will reach over $350 000 000 a year, a sum equal to one-third of the present National debt. And notwithstanding the appalling misery and loss of valuable lives from this one disease, typhoid fever would be unknown if the plainest and simplest rules of hygiene with reference to our drinking water were universally followed. In simple terms, if the typhoid germ or bacillus, as it is technically called, were excluded from our drinking water, the disease could not be established. While typhoid is not the only water-carried disease, to us it is the most important, if importance is to be measured by geographical extent, continuous presence and annual loss of life by disease. In the foregoing discussion of the quality of drinking water, while other objections may have been raised against the so-called potable water with which we are generally supplied, the main objection is to the possibility of its introducing the typhoid germ into the system.

Nature's process of purifying water is by distillation on a very large

scale. The waters of the lakes, rivers and sea are evaporated, the vapor ascends from the surface of the earth, is condensed in the clouds, and in due time returns to the earth as rainfall. After we have received the water again into our lakes and streams, or in the absorbent soil, we set about to pollute it with our sewage wastes, and, when thoroughly polluted, we drink it. This may be a very coarse way of stating the case, but is it not the fact? Nature attempts to supply us with a water free from dangerous organic matter and toxic properties, but we will not preserve it in this condition.

In regard to past efforts at water purification, and the attempt to build a standard of purity upon the reduced numbers of bacteria in the filtrate, certain facts have been established in connection with bacteria in water. Thus, the number is not a safe index of the quality of water. Well waters containing so few as four bacteria per cubic centimeter have been fatal to the lower animals, while lake water containing as many as 3 000 bacteria per cubic centimeter has produced no ill effects on the lower animals. Upon the other hand the number of bacteria is a fair indication of the amount of dissolved organic matter in water, but the determination of this by chemical tests is more reliable than to infer it from the number of bacteria. Generally, however, the water bacteria bear a close relation in numbers to the amount or proportion of dissolved organic matter.

While many attempts have been made and several well-known methods proposed to differentiate the typhoid bacillus from other bacteria found in water, none of these seems to be reliable, and the only certain test of the pathogenic properties of any suspected bacteria is by inoculation.

The ordinary water bacteria are not regarded as pathogenic, and pathogenic germs in a water sample are held to be adventitious, and not native to the water. This will partly account for the danger from a water containing few bacteria, and for the innocuous properties of some waters containing many bacteria, and emphasizes the belief now gaining ground, that numbers should not be received as an evidence of quality.

The introduction of a few water bacteria into a sample of distilled water may be followed by a large growth of the same species, but these cannot endure for many days, for lack of nourishment. If the water was absolutely sterile, and no organic matter imparted to it from the

atmosphere while introducing the bacteria, then no growth could occur, and in a short time the bacteria introduced would perish for lack of pabulum.

The typhoid bacillus and the cholera spirillum are not indigenous to water. Water is simply the carrier of these germs of disease, but owing to the difficulty of identifying them, especially the typhoid germ, no one can certainly say whether a suspected water contains the germ until inoculation tests have been made; and if pathogenic germs are found, then an expert judgment only can infer the presence of the Eberth bacillus, or some other bacteria having the same properties. However, if in the inoculation experiments simultaneous tests are made from pure cultures of the suspected bacillus and with the Eberth bacillus obtained from the spleen of one dead of typhoid fever, and the symptoms of the animals experimented upon are substantially the same, then it will be safe to declare the suspected water bacteria as the typhoid germ, even though its morphological and biological characteristics may not agree with the Eberth germ. Thus it may be a variety of the Eberth germ, or it may be a distinct germ capable of producing the same effects in the animal system. To illustrate this in a homely way, no one is likely to mistake beer for whiskey or *vice versa*, but both are known to produce intoxication. In like manner, two pathogenic germs may differ in their morphological and biological features enough to appear to be distinct species of bacteria, and at the same time possess similar toxicogenic properties.

It is unfortunate that cities are so unwilling to conduct such investigations of their water supply during epidemics of typhoid as will clearly demonstrate the condition of the drinking water at all times. As an illustration, one city of several is mentioned. During the later part of the year 1892 and early part of 1893 St. Louis was visited by an epidemic of typhoid fever, which increased the annual death rate from this cause 200 per cent. Investigations were made by the city authorities which clearly established the fact that the disease was practically confined to a district almost wholly supplied with water from the city mains; but, excepting this inquiry, which traced the cause to the Mississippi River water, no tests were made of the quality of the water at the time of the epidemic, or to compare it with the river water at other times when there was no epidemic of typhoid. There is no doubt that careful bacteriological tests would have shown the typhoid

bacillus of Dr. Eberth or Dr. Vaughan in greater numbers than usual in the water, or that the toxic properties developed by the germ when taken into the human system were then much more virulent than at other times.

To solve the question of an absolutely safe drinking water, the filtration to clarify the water should be combined with some process of distillation, and we shall have then, not only pure water, but water that looks pure, which is quite an object when you undertake to educate people upon the question of water quality.

As a matter of interest in connection with the subject of water quality and typhoid fever, the writer has compiled the statistics of typhoid from a number of our larger cities for the years 1890–91–92–93, giving the population, cases (when reported), deaths, and deaths per 1 000 of population (see Table A).

A comparison of the statistics in the table furnishes some interesting information. Thus the water drank in New York and Brooklyn seems to have been superior to that furnished to the city of Boston. Comparing Detroit with Buffalo, Cleveland, Chicago and Milwaukee, it appears that, while all depend upon the Great Lakes for their supply, the water drawn from the Detroit River is better than that from intake cribs set in the lakes a few miles from the shore, or at the foot of the lake, as at Buffalo. As a rule, the cities taking their water supply from the large rivers suffer more from typhoid fever that those that depend upon impounded water, like New York and Boston.

In Table B are given the data from epidemics of typhoid in the cities of Lowell, Lawrence and Springfield, Mass.; St. Louis, Mo., and Pittsburgh, Pa. The title and captions of the table fully explain its contents. Assuming the report of cases to be correct, the mortality from this disease, as shown by the column of percentage of fatal cases, is much greater in this country than in cities abroad.

TABLE A.

Typhoid Fever Statistics.

From the principal cities of the United States.—Compiled from Official Reports of Health Departments.

City.	1890.				1891.				1892.				1893.			
	Cases.	Deaths.	Population.	Deaths per 1 000.	Cases.	Deaths.	Population.	Deaths per 1 000.	Cases.	Deaths.	Population.	Deaths per 1 000.	Cases.	Deaths.	Population.	Deaths per 1 000.
Boston	......	191	437 245	$\frac{43}{100}$	966	154	461 093	$\frac{33}{100}$	765	137	474 063	$\frac{29}{100}$	......	148	487 397	$\frac{30}{100}$
New York	1 100	352	1 705 980	$\frac{21}{100}$	1 342	384	1 765 645	$\frac{22}{100}$	1 140	400	1 827 396	$\frac{22}{100}$	1 005	381	1 891 306	$\frac{20}{100}$
Brooklyn	......	218	853 945	$\frac{26}{100}$	......	174	880 780	$\frac{20}{100}$	....	162	962 530	$\frac{17}{100}$	......	165	990 891	$\frac{17}{100}$
Philadelphia	......	666	1 046 964	$\frac{64}{100}$	......	683	1 069 264	$\frac{64}{100}$	......	440	1 092 168	$\frac{40}{100}$	......	456	1 115 562	$\frac{41}{100}$
Baltimore	......	241	434 151	$\frac{57}{100}$	......	150	445 853	$\frac{34}{100}$	......	193	458 350	$\frac{42}{100}$	......	224	473 193	$\frac{47}{100}$
Washington	......	208	250 000	$\frac{83}{100}$	......	208	250 000	$\frac{83}{100}$	......	183	260 000	$\frac{70}{100}$	......	187	285 000	$\frac{66}{100}$
Pittsburgh	......	......	....	....	1 047	248	247 000	1	1 145	256	255 000	1	2 398	294	264 000	$1\frac{11}{100}$
Buffalo	......	......	....	....	......	129	255 664	$\frac{50}{100}$	.....	98	285 000	$\frac{34}{100}$	......	112	300 000	$\frac{37}{100}$
Cleveland	461	182	277 488	$\frac{66}{100}$	349	155	299 475	$\frac{52}{100}$	376	167	309 243	$\frac{54}{100}$	281	153	322 932	$\frac{47}{100}$
Detroit	......	41	230 000	$\frac{18}{100}$	......	30	230 000	$\frac{13}{100}$	. .	117	230 000	$\frac{51}{100}$	......	140	230 000	$\frac{61}{100}$
Chicago	......	1 008	1 100 000	$\frac{92}{100}$	......	1 997	1 300 000	$1\frac{54}{100}$	......	1 489	1 400 000	$1\frac{6}{100}$	......	670	1 500 000	$\frac{45}{100}$
Milwaukee	......	73	220 000	$\frac{33}{100}$	166	77	233 333	$\frac{33}{100}$	196	76	245 000	$\frac{31}{100}$	382	95	260 000	$\frac{37}{100}$
St. Louis	......	155	450 000	$\frac{34}{100}$	442	139	452 000	$\frac{30}{100}$	436	172	460 000	$\frac{37}{100}$	3 624	514	500 000	$1\frac{3}{100}$
New Orleans	.....	50	254 000	$\frac{20}{100}$	......	59	254 000	$\frac{23}{100}$	......	53	254 000	$\frac{21}{100}$	......	39	254 000	$\frac{15}{100}$
San Francisco	......	176	300 000	$\frac{59}{100}$	......	137	330 000	$\frac{41}{100}$	......	113	330 000	$\frac{34}{100}$	......	106	330 000	$\frac{32}{100}$
Cincinnati	......	197	296 600	$\frac{67}{100}$	270	186	300 000	$\frac{62}{100}$	245	121	305 000	$\frac{40}{100}$	214	134	310 000	$\frac{43}{100}$
Louisville	......	142	161 000	$\frac{88}{100}$	......	130	161 000	$\frac{81}{100}$	......	116	161 000	$\frac{72}{100}$	......	135	161 000	$\frac{84}{100}$

TABLE B.

Typhoid Fever.

Statistics Showing Fatality of Epidemics in Lowell, Lawrence and Springfield, Mass., and Annually for Pittsburgh and St. Louis.

Locality.	Date.	Cases.	Deaths.	Percentage of fatal cases.
Lowell, Mass	September, 1890	47	10	21
"	October, 1890	95	9	9.5
"	November, 1890	171	29	17
"	December, 1890	159	24	15.1
"	January, 1891	78	17	22
Total and averages		550	89	16.2
Lowell, Mass	November, 1892	19	3	16
"	December, 1892	70	10	14.3
"	January, 1893	38	10	26.3
"	February, 1893	14	7	50
Total and averages		141	30	21.3
Lawrence, Mass	November, 1892	14	4	28.6
" "	December, 1892	32	9	28.1
" "	January, 1893	72	3	4.2
" "	February, 1893	23	12	52
Total and averages		141	28	20
Springfield, Mass	July, August, September, 1892.	155	32	20.6
St. Louis, Mo	April, 1892; March, 1893	3 624	514	14.2
"	August, 1892	70	11	15.7
"	September, 1892	142	23	16.4
"	October, 1892	261	48	18.5
"	November, 1892	1 923	124	6.4
"	December, 1892	945	205	21 7
"	January, 1893	114	42	36.8
Pittsburgh, Pa	1891	1 047	248	23.7
"	1892	1 145	256	22.4
"	1893	2 398	294	12.3

DISCUSSION.

DESMOND FITZGERALD, M. Am. Soc. C. E.—A paper on the quality of water supplies needs no apology to this Society when we consider the army of engineers who are engaged in works of construction and improvement connected with the furnishing of pure water to cities and towns. Mr. Hill has well stated in the opening of his paper that, however much other sanitarians may aid the cause of good water, to the engineer must finally come the designing of works for public supplies. If there is one fact more gratifying than another to sanitary engineers, it is that so much attention is now paid to questions connected with the quality of water. It was only a few years ago that the question of quantity was the principal one to which water engineers devoted their studies. Probably few outside of the specialists realize how varied are the questions that enter into this subject of the quality of water.

We have to begin with a large classification of waters, each of which is subject to its own particular kind of troubles, and many of these are so subtle that it requires a lifetime to understand them. But I do not know of a nobler occupation or profession to which a man can devote his life than that of the improvement of water supplies.

It does not seem to me that we depend upon seeing the actual germs of disease in the water with the microscope or by inoculation from water samples in order to satisfy ourselves that they are present. We have had in Massachusetts several epidemics of typhoid fever in cities taking their water from sources infected with the typhoid bacillus where the death rate has immediately declined on cutting off the polluted water. A remarkable case has recently been presented fully by Mr. Mills before the New England Water Works Association in a description of a new filtering plant installed in Lawrence to rid the water of typhoid germs.

I was recently called to a small town containing 1 300 people, in which over 100 inhabitants were down with typhoid of a malignant type, and of these more than 10% died. In a large institution situated in the town with a separate water supply of its own not one person was taken sick with the disease. Happily I had no difficulty in persuading this town to throw away its source of supply and adopt another pure and abundant source close at hand. Under these conditions, there were so many circumstances pointing to the water as the source of infection that it did not require identification of the actual bacillus in the water.

In many cases a great deal of study is given to purifying a water,

when the same amount of study put into the question of preventing the pollutions from getting into it would do more good. During the past ten years we have devoted a great deal of time and money to this end on the Boston Water Works. The sewage from many of the towns has been pumped entirely out of the water-sheds and improved methods of construction have been adopted for the basins and storage reservoirs for the purpose of improving the quality of the water. We are now engaged in studying swamps existing on the water-sheds and providing plans for draining them, and many observations have been made upon the color of the waters coming from swamps and estimates formed of the probable colors after the improvements have been carried out. There is still, however, something to be said in favor of filtration in the case of almost any surface supply, however well guarded at the sources, and I look in the future to see filtration plants in more general use.

As is the case in many other large cities, we obtain our water supply in Boston by collecting and holding back water from streams during the wet months of the year, in order to distribute it during periods of deficiency in the flow or of long periods of drought. We have, of course, designed our storage so as to cover the longest drought in the past, of which we have a record, and we have made our storage sufficient to carry us through that drought; but it has been strongly impressed upon my mind recently that this is not sufficient to provide a uniform quality of good water. In order that this may be accomplished we must have a much larger amount of storage.

As is well known, surface water improves in quality when kept for a long time in thoroughly constructed basins which are free from organic matter. Now, when water is drawn out from these storage reservoirs at the end of the period of drought and the streams begin to resume a larger flow, then the city has to be supplied with water which has not had the advantage of long periods of storage. From this cause it is not possible always to distribute water of a uniform quality, unless a large surplus of storage is supplied, and it seems to me important that where a city or town is provided with water by means of equalizing the supply of a stream or by drawing from a natural lake, it is necessary that a very much larger amount of storage should be provided than that necessary simply to carry the town or city through the drought.

If the reports of the Boston Water Supply Department for the past few years are examined, it will be found that the number of organisms existing monthly at the surface, in the middle, and at the bottom of all our lakes and storage and distributing reservoirs are published in tables, and that the colors of these same waters and their temperature are given. These monthly averages are made up from weekly examinations. It will also be found that we have a well-equipped laboratory

devoted to microscopic work, and that we have a considerable filtration plant for the purpose of experimenting upon different methods of filtration. In fact, we spend from $12 000 to $15 000 a year upon experiments and analyses connected with questions affecting the purity of the water. This work has naturally revealed many facts of which we were not before aware. There may be some who think that money invested in this way is thrown away; but I think we may very well leave the future to decide this question. We feel, in Boston, that we have made a good investment in this work.

It seems to me questionable whether Mr. Hill's figures for the cost of separating the drinking water from the rest of a supply are sufficiently large. It has not been considered that we can accomplish this result in Boston with so small an expenditure per gallon.

Aeration has been referred to in this paper. It has been found on the Boston Water Works that no amount of aeration will affect the quality of the water, although we have more organic matter in the water than I should like to see. The truth is that the water contains sufficient oxygen in its natural condition, so that the addition of any more has no effect whatever. On the other hand it is true that there are many waters which are so deficient in oxygen and in which the organic matter is in such a condition that aeration produces wonderful effects in a very short time.

It does not seem possible to provide general rules which will apply to all waters. However much we do not know, there is one thing of which we feel sufficiently certain, and that is as to what good water really is; and this is the goal upon which we should keep our eyes and the standard to which we should work.

CHARLES FRANCIS, M. Am. Soc. C. E.—What may be called the germ of the typhoid bacillus may be generally found in the larger intestines of healthy people. These germs being introduced into the upper or smaller intestines through the medium of drinking water and finding there suitable pabulum, develop into the true typhoid bacillus.

WILLIAM E. WORTHEN, Past President Am. Soc. C. E.—As engineer in charge I have just completed a small water works at Southampton, L. I., in which the principle has been adopted of not exposing the water from the driven wells to the light till it is drawn by the takers. From the wells the water passes through the pumps into air-tight receivers or tanks of steel 6 ft. 6 ins. diameter and about 50 ft. long. There are three tanks which are filled at the maximum pressure of nearly 100 lbs. One of these receivers is open always to the village service; the other two are closed under the 100-lb. pressure. When the pressure in the first receiver falls to nearly 40 lbs., one of the reserved tanks is opened to raise the pressure in the mains and after another fall the third tank is opened. For fire purposes the tanks can be opened and adequate pressure secured promptly.

The water is strongly aerated by the compressors, which maintain the air pressure and volume, and the water is cool for domestic use. I am anxious to see its sanitary effects, as it will probably prevent the development of *confervæ*, and shall look to the report on vital statistics. With regard to the growth of microscopic organisms, I do not know of any standard authority, but think that sterilization should be used carefully, that "numerous bacteria exist in the digestive canal of a man in good health, and that they are not only innoxious, but they play an active part in gastric digestion and especially in the transmutation of albumens into peptones"; that they are necessary for the support of the white blood corpuscle and consequently of the red. My suggestion would be, sustain your own phagocyte and look to the effects as they can be seen naturally rather than to the present results of microscopic observation. It takes something more than microbes to produce ptomaines, there is a necessity of some pabulum and condition, and good health must depend largely on the surroundings and habits.

Charles H. Snow, Assoc. M. Am. Soc. C. E. (by letter).—Mr. FitzGerald has spoken of typhoid fever in a small town where those not using the common water supply were totally exempt from the disease. Such instances are common and furnish the most forcible argument for good water kept good. An interesting incident of the same kind was afforded by a small town in which I was located for some time.

The town was upon the sides of, and in the valley between, two hills. It had two sources of water supply. Mine water pumped from about 500 ft. below the surface, and surface water collected in wells. The mine water was freely given to all who sent for it, and those using it were not confined to any particular district, but were more or less scattered throughout the entire town. A miner having contracted typhoid fever elsewhere sickened upon one of the hill slopes, whence the fever presently spread over the entire population of 4 000 to 5 000 people. In one house sixteen cases developed. There were no instances of fever among those using mine water. As an illustration of the ignorance frequently displayed respecting water, while the fever was prevalent wells sealed by the Local Health Board were broken into by families insisting on the use of their own supply. I also recall seeing people dipping water from a small brook running through the town, which was practically a sewer, that a trip to the mine for water might be saved.

As the province of the physician is to cure disease, so that of the engineer is to prevent it, and a more pronounced method of popular instruction would be found useful in accomplishing this result, and might come within his province.

S. Whinery, M. Am. Soc. C. E. (by letter).—Mr. Hill has given the Society a very valuable paper upon the subject of which he treats. While he does not claim that there is much in it that is new, he pre-

sents a valuable summation of the present state of knowledge on the subject, and some pertinent suggestions as to the sanitary defects in present methods of water supply, and the means that are available for securing pure drinking water, and of avoiding its contamination before and after being collected or stored for use. From the evidence now in our possession, the problem of securing an uncontaminated supply of water for domestic use, is not only not yet practically solved, but is every day becoming more difficult of satisfactory solution. Unless collecting grounds are fully controlled, and carefully watched and guarded, there can be no certainty that uncontaminated water will be secured. As the population of the country increases and land becomes more valuable, it will become more difficult and expensive to secure control of collecting grounds, and to guard the supply against contamination. Even under the most favorable conditions, the danger of pollution will be very considerable.

The evidence is accumulating that we cannot rely on artificial filtration to remove from drinking water the germs and their spores that cause specific diseases. It was for a time supposed that filters of the Pasteur type could be depended upon to entirely remove deleterious elements from water, however polluted. It is now conclusively proven that in this we were but leaning on a broken reed. Combined filtration and oxidation by the use of filtering beds of sand and coarser materials has given great promise of success, as recently conducted in a painstaking and scientific manner under the careful supervision of competent experts and engineers. What the result would be under ordinary conditions of practice is at least problematic. The possibilities of lack of intelligence, carelessness, and management under engineers or superintendents more noted as ward politicians than as civil engineers or sanitary experts, are not pleasant to contemplate. Probably very few of us, in the present state of knowledge on the subject, would be willing to trust the health, and possibly the lives, of ourselves and our families to the use of drinking water known to be, in its natural condition, polluted and dangerous, if the only safeguard was purification by this method, under such management as too frequently controls the water supply of our cities.

The possibility of securing a perfectly safe water supply from deep wells in or near a great many of our cities, especially those situated within the glaciated regions of the country, is worthy, I believe, of far more attention than has been given it in this country. The evidence is accumulating of the existence of a great number of considerable streams of water flowing in the beds of pre-glacial streams, through beds of sand and detritus, so far below the present surface that the water has been subjected to the most perfect filtration, so that it is pure and wholesome beyond question. Such water supplies are often, though not so frequently, found in regions outside of those subjected

to glacial action. The possibility of securing such supplies should be thoroughly investigated in the vicinity of every city where there is any doubt about the purity of the supply of surface water. To this end, the discovering and mapping out of pre-glacial water-courses should receive more attention than it has heretofore, over the whole region of glacial action.

To me, the most important and suggestive part of Mr. Hill's paper is that relating to the purifying of water by boiling and distillation. This is not, of course, a new idea, but it is recalled to the attention of engineers by Mr. Hill at a most opportune time. Distillation is Nature's own method of water purification. Our standard of purity of potable waters is, and will continue to be, water distilled by the heat of the sun and condensed from the clouds by Nature's processes. The cup of water we collect as it falls from the clouds is, barring the slight possibility of contamination by germs and impurities floating in the air, absolutely pure and wholesome for domestic use. No matter how impure it may have been before its distillation, it may now be used with perfect safety. It is possible that a portion of it may have come from the filthiest cesspools, another portion from the excrement from fever hospitals or the waste from diphtheria wards, and still another portion may have come from the filthy haunts of cholera patients in the far East, yet we may now drink it with impunity.

Distillation is the one method of water purification that all are agreed is perfectly effective and reliable.

The only question about the practicability of this method is that relating to cost. Mr. Hill has treated of this part of the subject with considerable detail, and has shown that a supply of absolutely pure water for domestic purposes can be secured at a cost, which, considering the great benefit that would result, is certainly worth incurring. I believe, however, that the cost may be materially reduced below Mr. Hill's estimate. It will be noticed that he contemplates condensing and cooling the distilled water by surface condensers cooled by the 97 or 98% of water that must be provided for purposes other than drinking. This would mean the wastage of all the heat given up in the condensation and cooling of the distilled water. If, instead of thus wasting this heat, it be utilized for heating the water to be distilled, the process would be cheapened to that extent. This might be readily accomplished by passing the steam to be condensed and the hot condensed water through pipes surrounded by the incoming water on its way to the boilers. Just how much of the original heat could thus be returned to the boilers, I am not prepared to say; but it is, I think, safe to say that 40% of it could be thus saved and re-utilized. Assuming that this is possible, it would not only reduce in the same ratio the cost of fuel and attendance, but the cost of the plant for distillation also. Making

such modifications as this assumption will allow, and making some other changes in Mr. Hill's estimate as seem warranted, we shall have the following as the cost of treating 1 000 000 galls. per day:

Cost of plant for distillation....	$135 000
Cost of separate system of pipes for a city of 160 000 population......................	450 000
Cost of plant for aeration of water if thought necessary..............................	15 000
Total..................................	$600 000

COST OF OPERATING FOR ONE YEAR.

Interest on investment at 4 per cent...........	$24 000
Repairs and renewals at 5 per cent............	30 000
Cost of fuel..................................	91 500
Cost of labor and superintendence...........	24 000
Total..................................	$169 500

which, divided by 365 000 000 galls., gives as the cost of purification per 1 000 000 galls, about $465.

I have no data at hand as to what amount of water would be necessary for drinking and such other domestic purposes as would insure freedom from specific diseases caused by contaminated water, but I think it would be safe to assume that the amount would not exceed 6 galls. per capita. On this assumption 1 000 000 galls. would be sufficient for a city having a population of 160 000, and the cost per capita per day would be less than three-tenths of 1 cent, and the cost for a family of five persons would be 1½ cents per day, or about $5 50 per year.

It is to be anticipated that the most serious difficulty in operating such a system will be found in the proper regulation of the use of the purified water. On the one hand, some families would be disposed to use the pure water for other than the purposes for which it is intended, and others, either from carelessness or to avoid the cost, would be likely to omit its use. The first difficulty might be met by the use of meters at every house, and for the use of such meters a reasonable rental would have to be charged.

The opposite difficulty could, perhaps, be best met by requiring by municipal ordinance the use of the pure water for certain stipulated purposes, and making it the duty of sanitary inspectors to see that the ordinance was complied with.

What I have said is intended only as an outline of what might be done in this way toward the furnishing of an absolutely pure supply of water for domestic use. The subject is of such great importance as to merit, in my opinion, the most careful consideration and investigation of the system suggested, by water-works' experts and sanitary engineers.

William P. Mason, Esq. (by letter).—The author of this paper appears to be a believer in the power of water to spread disease, but some of the statements and quotations advanced by him would certainly go far to unsettle the public mind and cause lack of faith in the teachings of some able masters.

He says : "While water is held to be a carrier of disease germs, the writer is not aware that any investigator has ever claimed to have seen these germs in water, even under the highest powers of the microscope ; and the evidence that water is such a carrier of pathogenic bacteria is obtained by inoculation from water samples of nutrient media in test tubes or on culture plates."

"The typhoid bacillus in water has never been seen with the microscope without previous cultivation of the germ in nutrient media. Nor has it ever been demonstrated, so far as the writer is aware, that the presence of bacilli in water can be proven, excepting by delicate and difficult bacteriological processes."

That single individuals of the Eberth bacillus should escape direct detection is hardly to be considered surprising, in view of the enormous volumes of water in which they are suspended. However difficult the processes of modern bacteriology may be for a tyro, it is hardly just to consider them unreliable in the hands of such experts as Koch, Pasteur or Eberth ; and, if any one of these men, or of many others who might be named, should state that he had secured pure cultures of a specific germ under circumstances which excluded the possibility of extraneous contamination, we should be exceedingly liable to believe him.

Again : "It is well understood that the infective element of typhoid fever can be present in water and the chemical test be powerless to disclose it."

True enough, but it does not complete the story. During an investigation following a serious outbreak of typhoid fever in the Tees valley, England, the medical officer of the Local Government Board, London, caused preparation to be made of samples of pure water to which small quantities (50 and 25 parts per 1 000 000) of typhoid dejecta had been added, and these samples were then submitted to prominent water analysts for examination. No results upon which an adverse report could be based were obtained. The contaminated waters were pronounced pure. It must be remembered that the polluting material, as weighed, being very largely water, the pollution appeared greater than it really was. Fifty parts per 1 000 000 of the typhoid dejecta corresponded to only 4 parts per 1 000 000 of total dry residue. As a natural

result of these experiments, the purely chemical methods of water examination received very severe criticism, and the advocates of the exclusively bacteriological processes were correspondingly elated, for here were known instances of fatal contamination which the chemists had failed to diagnose. Let this, however, be said in defence. In cases as they occur in practice a serious addition of typhoid dejecta has much that is associated with it of a comparatively inoffensive character, but which reacts with the chemical reagents and tells the tale of sewage contamination, although the analyst cannot venture to state the exact nature of the source from which the pollution is derived.

Not long since the writer claimed that the river water furnishing a large eastern city was contaminated with up-stream sewage, the opinion having been based, not alone upon an analysis of the water at the intake, for the river was large and the consequent dilution great, but upon the difference between that analysis and one of the water taken from above the sewage inflow. The difference was small, but it was noticeable, and there was no other sufficient explanation of its existence than the one given. Later on typhoid fever broke out in the upper valley, and epidemics developed not only in the city in question, but in all the neighboring towns using the river water for supply. Closely related cities and towns, which received their water from other sources, were not affected. Space does not permit of giving details, showing how clearly the case stood against the river water, but it is interesting to note that typhoid germs were most carefully sought for and were not found. That they were nevertheless present, there can be but little doubt. Chemical analysis in this instance did certainly not detect the presence of typhoid, but what it did do was to warn the people, months before the typhoid appeared, that they were drinking diluted sewage, and that they must beware of the time when that sewage should come from pathogenic sources.

The paper in question goes on to say:

"The popular impression that the Koch, or Finkler and Prior, comma bacillus is the cause of cholera is fallacious, or, at least, not proven. The same remark applies to the typhoid bacillus of Eberth. The proof is still wanting that this will cause typhoid."

This last is a quotation from Sternberg's "Manual of Bacteriology," but it is very misleading because it is incomplete.

What Sternberg really says is this:

"Recent researches support the view that the bacillus described by Eberth in 1880 bears an etiological relation to typhoid fever; and pathologists are disposed to accept this bacillus as the veritable germ of typhoid fever, notwithstanding the fact that the final proof that such is the case is still wanting.

"This final proof would consist in the production in man or in one of the lower animals of the specific morbid phenomena which characterize the disease in question, by the introduction of pure cultures of the

bacillus into the body of a healthy individual. Evidently it is impracticable to make the test upon man, and thus far we have no satisfactory evidence that any one of the lower animals is subject to the disease as it manifests itself in man."

Now, that is a very different statement, and conveys a meaning greatly unlike the one suggested by the partial quotation referred to.

The paper again says :

"Absolutely healthy persons have been known to reject the Eberth bacillus in their excrement, showing such, probably, to be in the intestines at all times."

This is an error. The *bacillus coli communis*, which closely resembles the typhoid bacillus, is constantly present in the intestines of healthy persons, and may lead to confusion, but no position such as the above quotation indicates is now occupied by bacteriologists. In this connection Sternberg (an authority frequently quoted in the the paper) says : "No competent bacteriologist, so far as I know, has claimed to find the Eberth bacillus in the fæces of healthy individuals."

As to the doubt thrown upon the correctness of the view that Koch's comma bacillus is the cause of cholera, the work of Sternberg will hardly endorse it. In this connection Sternberg says:

"The etiological relation of this spirillum to Asiatic cholera is now generally admitted by bacteriologists." And also : "The most satisfactory evidence that this spirillum is able to produce cholera in man is afforded by an accidental infection which occurred in Berlin in the case of a young man who was one of the attendants at the Imperial Board of Health when cholera cultures were being made for the instruction of students."

As to the statement in the paper that "fatal cases of typhoid have been attended with none of the Eberth bacillus in the fæces, or in the intestines, the seat of the disease," it is to be noted that Gaffky's investigations show it to be by no means a serious objection. He considers the technical difficulties surrounding a hunt for the bacillus, in some few instances, so considerable as to readily account for a small percentage of negative results; and he cites instances where he found the "germ" after an amount of patient search which extended far beyond the point where the average observer would have ceased work and placed a negative report upon record.

Finally the paper has much to say upon the imperfections of modern filters and the danger of using water therefrom. It goes without saying that pure water is better than purified water, but then the former is often unattainable and we have to do with the latter or go without.

Especial stress is laid upon the fact that even when the filtration is so successfully accomplished as to leave in the filtrate only one or two bacteria per cubic centimeter, yet "a person may imbibe from 250 to 500 bacteria in drinking a single glass of water, some of which may be

pathogenic and produce typhoid fever or some less dangerous disease." Such a degree of excellence in filtration as the obtaining of a filtrate with only one or two bacteria per cubic centimeter is, indeed, rarely attained; yet the public have a right to look with confidence upon a plant which does not pretend to accomplish half that amount of purification.

Consider for a moment what the Altona filters did for that city during the Hamburg cholera epidemic of 1892. The Altona water was taken from the Elbe River at a point below the outfalls of sewers carrying the cholera-infected sewage of 800 000 people. Yet Altona had no cholera (except imported cases), while Hamburg was scourged by it. The cities are practically one, a stranger being unable to tell the dividing line.

Take the numbers showing the efficiency of the Altona filters during one month of 1892.

The bacteria in the raw Elbe water per cubic centimeter varied from 9 370 to 44 140, with an average of 28 667. The average number in the filtered water was 90. This meant a removal of 99.69% of germs of all kinds, 0.31% still remaining. The filtrate was by no means sterilized, but the city was protected from a cholera epidemic under circumstances trying in the extreme. As to the efficiency of sand filtration for water purification, the following figures are given for results found at the Lawrence experiment station, the filters having been operated with water containing known quantities of bacteria:

Rate in gallons per acre daily.	Kind of bacteria added.	Per cent. removed.
1 500 000	B typhi. abdom.	99.93
3 000 000	B. prodigiosus.	99.95

This reduction of the number of germs in a given volume of water is possibly equivalent to a dilution of the unfiltered water with a very large volume of a pure supply, and in this connection the writer of the paper says: "Dilution may reduce the chances of any single individual imbibing a fatal germ, but the germ itself will be just as dangerous when it is imbibed."

This is, doubtless, true, if the individual be especially susceptible, for it has been experimentally shown that a single germ may produce fatal results when injected into an animal very prone to the special disease, but as it has been also shown that when the animal is not very susceptible, the "dose" of bacteria has to be enormously increased to produce any result. We incline to believe that some similar reason may account for the apparent immunity of that fraction of a community which has been equally exposed, but which escapes contagion.

What the paper says regarding the unsatisfactory results observed

where household filters are in use is unfortunately very true, but the fault is more commonly with the attendant than with the filter. The common belief is that a filter, once established, is good for all time, and I could tell tales of what I have seen in otherwise well-organized establishments that would stagger belief. I do not approve of general household filtration, as I believe purification can be better and more cheaply done on the large scale by the municipal authorities, but I cannot think that the Pasteur filter should be swept aside like the worthless contrivance the paper calls it. My experience is that, with proper care, it is efficient. Extended tests were made with it for the Connecticut Board of Health in 1892, which show that it may be depended upon, if the porcelain cylinder be cleaned and sterilized once a week.

Freundenreich has obtained similar results, and has also shown that the length of time during which the filter is efficient depends upon the temperature.

John W. Hill, M. Am. Soc. C. E. (by letter).—The one grand proposition in connection with the quality of water supplies is that a polluted water is the immediate or original cause of typhoid fever and the typhoid symptoms in typhoid malarial fever, and that a water at all times wholly free from the typhoid bacillus can never produce typhoid when used as a beverage, nor in any other way.

Such water is very difficult to find in Nature, or, being found, it is difficult to preserve it free from contamination.

Water gathered at great elevations above habitations and the operations of husbandry, and impounded in large deep reservoirs, is perhaps the nearest approach to sterilized water in Nature which we can hope to make.

Rivers which receive sewage at any point above or at short distances below water-works intakes can never be regarded as safe sources for drinking water. The same statement applies, but generally with less force (excepting Lake Michigan at Chicago), to lakes which are the outfalls for town sewage.

Sand filtration abroad has generally been attended with good results, but it cannot be relied upon to remove all disease germs, and in this country, from my own experience, the continuous sand filter as usually operated is not to be depended upon as a safeguard against disease germs in water. From some investigations which I am now making of the water of the Passaic River, N. J., I find enormous growths of bacteria on gelatine and agar plates, even after the water has been passed through one of our celebrated mechanical filters. Plates being inoculated simultaneously from unfiltered and filtered water, the relative growths of bacteria from the filtered water is very startling. The results of the investigations mentioned above when completed will be published in due time in one of the engineering journals.

In replying to the criticisms of Professor Mason, the writer believes

that water is the carrier of the typhoid and other disease germs, and he is willing to accept the present evidence as proof of this. There is no desire to "unsettle the public mind and cause lack of faith in the teachings of some able masters," and if there is anything in the paper which rejects the conclusions of Eberth, Koch and other investigators of the typhoid bacillus, the writer must confess to such a degree of obtuseness as not to be able to recognize it. If the writer has not made his position clear upon this question in the paragraph at the bottom of page 135 *et seq.*, then the fault lies in the choice of language and not in intention.

In stating that the proof is still wanting that the Eberth bacillus will cause typhoid, the reference was made to Dr. Sternberg's excellent "Manual of Bacteriology," where those who may be interested in this phase of the water question can examine the authority at their convenience and draw their own conclusions.

It might have been better to quote at length from Dr. Sternberg's work, but it was not considered necessary, and would not have changed the substantial fact that "the proof is still wanting" that the Eberth bacillus will cause typhoid in man, however confident Dr. Sternberg, Prof. Mason, and others may be that it will. In this opinion the writer shares, but until inoculation experiments have been made upon man (and this is obviously impossible in an enlightened and humane age), there will remain some foundation for the opinion so often expressed of the fallibility of the germ theory of disease. While the evidence clearly shows the connection of the typhoid bacillus of Eberth with the typhoid fever symptoms, and probably shows it as the cause of typhoid, the positive evidence can be had only in the manner pointed out.

That the processes for the differentiation of the typhoid bacillus from other water bacteria are both "difficult and delicate," even in the hands of a master, Professor Mason is referred to Dr. Vaughan's "Bacteriological Study of Drinking Water," 1892, and to Dr. Sternberg's "Manual of Bacteriology," page 349, last paragraph, as well as to his own paper on "Some Cases of Drinking Water and Disease," 1891, when, notwithstanding his careful attempts at cultivation of the typhoid bacillus from the infected waters of the Mohawk and Hudson rivers, he failed entirely to find the germ. There is no doubt of the typhoid bacillus being in the water at the time of its examination by Professor Mason, but his attempts to show the existence of it were entirely negative. He gives a satisfactory reason for this, but his reason only proves that an attempt to demonstrate the existence of the germ in water is very difficult, and he is undoubtedly aware of the fact that the tests for the germ are very delicate and not very reliable.

The paragraph quoted by Mr. Mason on page 165 was, upon the

advice of Dr. Sternberg, withdrawn before the paper was read at the Convention, and the following paragraph was substituted:

"In order to approach the question of water pollution properly, it must be borne in mind that while polluted water is held to be the cause of certain diseases, exactly how it acts on the human system is not well known. Bacteriologists generally regard the Koch cholera bacillus and the Eberth typhoid bacillus as the causes of these diseases, but this view is not shared by all physicians as it should be if the proof of cause was sufficient; although common prudence should decide us in rejecting any water known to contain the cholera or typhoid bacilli, whether these germs be regarded as the cause or result of disease, since they indicate the presence of the cause even if not themselves the cause."

In regard to the remarks upon the incompetency of any known method of filtration to prevent typhoid fever, the writer can only add to what he has already stated in discussing this aspect of the quality of water, that while filtration may mitigate, it cannot be depended upon to wholly remove the evils of a polluted water. Thus the removal by filtration of 99% of the bacteria is accompanied by a reduction of 75% in the typhoid fever death rate, showing that the 1% of bacteria remaining in the water are as virulent in a pathogenic sense as 33% of the bacteria removed. Professor Mason has stated* that during the epidemic of typhoid fever in Albany and vicinity (1890–91) "boiling of water for drinking purposes was recommended, and no typhoid developed among families who followed the recommendation," clearly indicating that absolute safety from a water of known pollution lay in the direction of sterilization and not in the direction of filtration. This, in short, is the writer's position with reference to the problem of eliminating typhoid fever from the list of diseases by which we are now confronted. Let all polluted water be properly sterilized and there will be no typhoid among the people who drink and cook exclusively with such water.

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* "Notes on Some Cases of Drinking Water and Disease." Professor William P. Mason, 1891.